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A LINEAR DISPLACEMENT TRANSDUCER
FOR HIGH RATE MULTIPLEXING SYSTEMS

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A LINEAR DISPLACEMENT TRANSDUCER FOR HIGH RATE MULTIPLEXING SYSTEMS*

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Introduction

An attempt has been made to design the ultimate velocity measurement system. Whether or not we have succeeded will be left up to the reader.

Displacement transducers are used to measure the velocity of small samples of metals exposed to underground nuclear explosions. The velocities range up to 200 cm/s with fairly high accelerations.

Multiplexing the transducers is necessary to reduce the number of cables needed for a large number of gages. The multiplexing is accomplished by sequentially interrogating the gages with short duration pulses and diode mixing the gage outputs onto a common signal cable.

The gage is basically a transformer. The coupling between primary and secondary windings is controlled by inserting a copper vane in an air gap in the transformer. Eddy currents are produced in the copper which oppose the action of the flux in the air gap. The primary to secondary coupling is proportional to the area of the air gap not blocked by copper.

The vane, which is the moving element, is made from thin printed circuit board material with a pattern etched in the copper. The gage's output amplitude versus position curve is determined by the shape of the pattern.

The length of travel that can be measured is determined by the desired resolution. We have used full scale travels of 1/2 to 12 cm. The accuracy is determined by prior calibration and external equipment stability.

The gage has proved to be very reliable in field use. Ninety transducers have been multiplexed onto two 50-ohm signal cables with the position of each gage monitored every 100 microseconds.

Design

Principle of Operation of Vane

A good way to control magnetic flux at radio frequencies is with a barrier made of material having low electrical resistivity, such as copper or aluminum. Magnetic flux in attempting to pass through such a barrier induces voltages in the barrier material which give rise to eddy currents. These eddy currents oppose the action of the flux, and in large measure prevent its penetration through the barrier. The thickness of the material should be several times the skin depth at the frequency of interest.

*Work performed under the auspices of the United States Atomic Energy Commission.

Principle of Operation of Transformer

The design goal was to make the gage be a good pulse transformer for a 100-volt, 0.3-microsecond wide pulse from a 50-ohm generator.

As seen in Figure 1, E-cores were used to form the transformer. We have also successfully used slotted torroids. The best material was Ferroxcube 3E2A ferrite. Nickel-iron could be used if very thin laminations were used.

A 30-mil gap was necessary to accommodate thick enough copper and strong enough fiberglass backing.

Two transformers, with primary windings in series, were used in an attempt to maintain constant input impedance with vane position variation. As more copper is inserted in the gap of one transformer, its input becomes more inductive. The other transformer, with copper being removed, helps balance the total input impedance. The shunt 100-ohm resistor also helps reduce the affect of the input inductance.

The leakage inductance of each transformer is reduced by winding the turns on a non-shorting layer of thin copper tape.

The secondary of one transformer is terminated with a 50-ohm resistor, while the other secondary goes to the 50-ohm transmission system.

Construction

Figure 2 shows the assembly of the ferrite E-core displacement transducer. The body was injection-molded using Epocast epoxy molding compound. The vane-holder is machined from aluminum. The shaft through the linear ball bearing can be either steel or aluminum. There are several reports on construction details of the gage.^{1,2}

Figures 3, 4, and 5 show the assembly of a displacement gage used to measure bulkhead or background motion in conjunction with the standard size gage. It is smaller in diameter and uses slotted ferrite torroidal transformers.

Results

Figure 6 shows a typical calibration curve for the type of gage shown in Figure 2.

The gage did not turn out to be a very good pulse transformer. The large air gap produces a fairly large leakage or series inductance. Therefore, the input impedance is somewhat inductive and the pulse risetime is degraded. The transformer should be designed around a particular input pulse shape.

The gage, when used in our system with a 7-bit analog-to-digital converter, can resolve approximately 10-mils displacement over a range of 2 cm. The non-linearity of the calibration curve is due primarily to the magnetic flux

fringing beyond the transformer core area at the air gap. The copper vane cuts this nonlinear flux, in addition to the linear flux in the gap.

The best way to improve on the gage would be to reduce the air gap width. This would improve the transformer's pulse response and the linearity of the calibration curve.

Measuring impulse in the field environment has been very successful with this gage. Using a predicted impulse for a particular experiment, the moving mass of the gage is adjusted to give full travel (2 cm) in about 20 milliseconds. This allows many data points to be obtained during that time for an accurate measurement of velocity. The first few data points, which might be noise, can be thrown away.

Bulkhead plate motion is measured with the same type of displacement gage. This motion can sometimes be seen in the impulse gage velocity curve.

The above displacement transducer concept has been very useful due to the design flexibility in size, shape, measurement requirements, and electrical characteristics. It may not be the ultimate, yet, but give it time.

References

- ¹C. Brown, UCLLL, private communication.
- ²J. Pruner, UCLLL, private communication

Figure Captions

- Figure 1 Electrical circuit.
- Figure 2 Mechanical assembly.
- Figure 3 Background motion transducer assembly.
- Figure 4 Close up of electrical circuit.
- Figure 5 Close up of electrical circuit and copper vane.
- Figure 6 Calibration curve of typical displacement transducer.

ELECTRICAL CIRCUIT

PATENT - FIG. 3

FIG. 1

FIG. 2

PETERS FIG. 5

Calibration Curve

Output (ADC Units)

PETERS - FIG. 6

Distance (inch)